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Adoption of good practices by tomato retailers in Kaduna and Oyo States, Nigeria

[version 1]

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Abstract

Food markets are central to food security and livelihoods in low- and middle-income countries, yet their effectiveness is often constrained by inadequate infrastructure and weak governance, which hinder the maintenance of food safety standards. This study examines the determinants of good hygiene and handling practice adoption among tomato retailers in two Nigerian states that reflect the country's socioeconomic diversity—the relatively poorer north and the more affluent south. Adoption rates were generally low: only 20–50% of retailers complied with most recommended practices, and on average, fewer than two of the five assessed practices were being implemented. Adoption was positively associated with traders' education levels, access to clean water, and market governance characteristics, particularly the presence of democratic and inclusive management structures. These findings highlight the need for multi-level, context-sensitive interventions to strengthen food safety in informal markets. Policies promoting trader education, investment in water and sanitation infrastructure, inclusive and democratic market governance can enhance food safety, protect public health, and inform broader strategies for improving informal food systems across low and middle-income countries.

Keywords

Tomato retailers, Hygiene practices, Informal markets, Market governance, Food safety



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1. Introduction

Proper food handling practices are essential across the food supply chain to ensure the availability of affordable, safe, and nutritious food. Although contamination can occur at any stage, the risk is strongly influenced by the health, hygiene, and compliance of food handlers with safety regulations and best practices (Aljasir, 2023; Gemeda et al., 2023; Mama & Alemu, 2016). In many low- and middle-income countries (LMICs), concerns are growing about the handling of fresh produce in traditional open-air markets that often lack basic sanitary infrastructure and clean water (Amoah et al., 2005). Despite these conditions, such markets continue to serve the majority of consumers (Abatan et al., 2025; Lagerkvist et al., 2013), making them critical nodes for safeguarding public health.

In addition to poor market infrastructure, such as limited access to water, inadequate storage facilities, and waste management systems, trader practices further heighten the risk of contamination. Traders commonly display vegetables on the ground near open drains or leave food uncovered and exposed to insects and dust (Abass et al., 2018; Amoah et al., 2011). Stacking vegetables in jute sacks or raffia baskets and using open trucks for transport also contribute to physical damage and spoilage (Zu et al., 2014). While many traders understand the importance of hygiene, studies show that knowledge alone is insufficient for safe practices. Obayi et al. (2020) reported that traders in Nigeria recognized sanitation's importance but were constrained by poor drainage, limited waste bins, and overcrowding. Similarly, Ekor et al. (2022) found that although 54% of traders in Calabar, a city in Nigeria had good knowledge of waste management, only 16% practiced proper disposal. This gap between awareness and behavior underscores the influence of environmental and institutional constraints.

Empirical evidence further demonstrates how poor handling compromises food safety. Abatan et al. (2025) found that while most vegetable traders in Ogun State, Nigeria washed their produce before sale, only half replaced wash water as recommended, increasing *E. coli* contamination risks. In Benin City, Nigeria, cutting boards and knives used by traders were frequently contaminated because only 52% cleaned them with detergent (Igbinosa et al., 2024). These findings illustrate that even where basic hygiene knowledge exists, compliance remains inconsistent.

Despite growing attention to food safety in LMICs, limited research explores how market-level characteristics and governance structures affect trader behaviour. In addition, many existing studies focus on one or two markets (Gemeda et al., 2023; Kariuki et al., 2017) or on markets in urban settings (Abatan et al., 2025; Resnick et al., 2019; Young et al., 2017, 2019), or rural areas (Subramanian & Qaim, 2011; Wenndt et al., 2025). Few studies consider traders in both rural and urban areas (or across multiple regions in the same country) allowing for comparisons across traders in different contexts to learn if and how challenges and thus recommended policy or donor interventions vary. In addition, very few studies (none the authors are aware of) have considered market governance alongside trader characteristics and market infrastructure.

This study addresses these gaps by analyzing hygiene and handling practices among 500 tomato retailers across markets in rural and urban areas of Kaduna and Oyo States, Nigeria, two regions with distinct demographic and infrastructural profiles. Kaduna (northern Nigeria) has lower education levels and higher poverty rates (approximately 75%), whereas Oyo (southern Nigeria) is more affluent, with about 45% poverty (CableIndex, 2025; Osuntade et al., 2025; Otekunrin et al., 2019). Using regression models that account for trader and market characteristics, the study identifies factors influencing the adoption of five recommended hygiene and food handling practices. By comparing patterns across regions, it provides updated empirical evidence on traders' knowledge, attitudes, and practices and offers actionable insights for designing targeted interventions to strengthen food safety governance and reduce the burden of foodborne diseases in Nigeria's tomato value chains.

The remainder of this paper is structured as follows. Section 2 presents the study materials and methods, including the study area, sampling, data collection, and analytical approach. Section 3 reports the empirical results, Section 4 discusses key findings, and Section 5 concludes with policy implications.

2. Materials and methods

2.1 Study area

The study was conducted across the three senatorial districts in both Kaduna and Oyo States. Kaduna State is in Nigeria's Northwest region and is one of the country's most populous states. As of 2025, its population is projected at approximately 9,857,682, representing a 9.1% increase from the estimated 9,032,200 in 2022 (PostalCodeng, 2025). The state is recognised for the high profitability of peri-urban vegetable farming, particularly in crops like tomatoes, cucumbers and cabbage, owing to favourable climatic conditions and strong market demand (Saras et al., 2023). Similarly, Oyo State, situated in the Southwest region of Nigeria, ranks among the most populous states with a projected 2025 population of about 8.54 million, driven by urbanisation and a youthful demographic profile (Kenneth, 2025). The

state has demonstrated significant adoption of sustainable vegetable production technologies, with many farmers implementing improved crop varieties and water management practices, thereby boosting productivity and promoting sustainability in the sector (Oyetoro et al., 2018). These two states were selected based on their relevance in vegetable production and distribution in Nigeria (NAERLS (National Agricultural Extension and Research Liaison Services) & FMARD (Federal Ministry of Agricultural and Rural Development, 2022)). While not nationally representative, they reflect significant regional differences in climate and agroecology, socio-economic development and cultural norms, thereby providing valuable insights into how such factors influence hygiene and vegetable handling practices.

2.2 Sample and survey data collection

Our sample consists of 500 tomato retailers, comprising 370 from Kaduna State and 130 from Oyo State. Tomato retailers were chosen for this study because of the growing importance of tomatoes as a commonly consumed food item in Nigeria, whose value chain has been expanding rapidly (Parkhi et al., 2023; Wineman & Liverpool-Tasie, 2022). However, several studies have reported their contamination with pathogens such as *Escherichia coli*, coliforms, and *Bacillus* spp., with increased risk as tomatoes move along the supply chain from farms to markets (Abatan et al., 2025; Aernan et al., 2015; Shenge et al., 2015). Water used by traders, particularly for washing and sprinkling vegetables, also represents a critical route of microbial contamination, as it can harbour faecal coliforms and pathogens like *E. coli* (Omotayo et al., 2017).

To select tomato retailers for our study, we began with a comprehensive listing (census) of all tomato retailers operating in wholesale markets across the two study states: Oyo and Kaduna. Wholesale markets were used as the base point for this study because the study team already had a census of all the wholesale markets for tomatoes in the two study states and confirmed that retail activities occurred in most of these markets (~80%). While this approach implies that we have not captured a non-trivial segment of the tomato retailer population (e.g. those operating in urban and peri-urban neighbourhoods and purely retail markets), this sample accurately captures the activities and market conditions of retailers operating in food wholesale markets with both wholesale and retail activities ongoing. Many of these markets have similar conditions as a lot of the purely retail markets that were too numerous to capture and for which there is no sampling frame currently existing. Thus, we acknowledge that we do not have a representative sample of all retailers in Kaduna and Oyo States but provide an adequate sample from which to learn about the factors associated with the adoption of good hygiene and handling practices among tomato retailers in Nigeria.

To determine the required sample size, we calculated the finite population-corrected sample size for a simple random survey, following established methods (Cochran, 1997; Linden, 2013; Lohr, 2010). We assumed a 95% confidence level and a 5% margin of error ($\pm 5\%$), with a conservative estimate of population variance at 0.5, commonly used to ensure a sufficiently large sample size when variability is unknown. The standard formula for the required sample size under these assumptions is 384. To ensure our sample size exceeds this minimum and accounts for potential non-responses or data quality issues, we targeted a total sample of 500 tomato retailers.

For sampling, we applied a stratified random sampling approach to ensure gender balance and to reflect regional differences based on the listing data. Specifically, we selected equal numbers of male and female tomato retailers in each state. In Oyo, we sampled 65 male and 65 female retailers (totaling 130), and in Kaduna, we selected 185 male and 185 female retailers (totaling 370). This approach ensures that the overall sample of 500 tomato retailers is proportionately distributed across genders while aligning with the initial population distribution across states. Sample weights were assigned to respondents to reflect their representation in the listing. In addition to demographic data (e.g., age, gender, and education level), the questionnaire covered specific handling practices (such as sorting products and washing) as well as hygiene behaviours such as handwashing after toilet use. Given the sensitivity of some questions, enumerators were specially trained to ask them in a non-judgmental, conversational manner. They also made direct observations of traders' practices to supplement self-reported data. A pilot test was conducted in markets within the study states but not included in the main study to ensure clarity and reliability.

2.3 Empirical analysis

Our empirical analysis leverages on statistical analysis to explore the drivers of trader adoption of good hygiene and handling practices. We use this empirical analysis to supplement descriptive statistics (means) calculated for each variable and used to describe the study sample as well as the retailers' adoption of good hygiene and food handling practices. We consider five good hygiene/handling practices namely (1) washing of tomatoes (2) routine water changes every 4 hours, (3) Handwashing with soap and water after using the toilet (4) sorting tomatoes after purchase to remove those that are of lower quality or bad and (5) if a trader's tomatoes are sold on a raised platform. The selection of these practices was drawn from a review of the literature on food safety (Akoachere et al., 2018; Aljasir, 2023; Boakyee et al., 2023; Hamed & Mohammed, 2020; Magqupu et al., 2023; Nizame et al., 2019; Solomon et al., 2018).

The explanatory variables considered include trader demographic variables (e.g. gender, age, education), scale of the enterprise measured by the number of hired employees and market level characteristics such as the location of the market (state, whether it is in a rural or urban areas), market governance characteristics (if market leaders are elected and the presence of women in the market leadership committee) and the number of toilet to trader ratio.

Given the binary nature of our adoption measures (equal to 1 if trader i adopts a practice and 0 otherwise), we evaluated the factors that influence adoption with a series of probit models. The statistical model is based on a cumulative distribution function and the probability that a trader adopts a practice ($Y = 1$) under given conditions can be calculated as:

$$p_i = \text{Prob}[Y = 1 | x_i] = \Phi(X_i'\beta) \quad (1)$$

With p_i being the probability that trader i adopts a practice. The cumulative distribution function of a standard normal variable is represented by Φ , while X_i' is a list of k characteristics describing trader i and β represents the respective parameter estimates. To determine the effect of each variable we estimated the marginal effect for each trader or market characteristic and presented the average. Holding other variables constant, the marginal effect of each market characteristic can be expressed as:

$$\Delta = \Phi(\bar{X}\beta, d=1) - \Phi(\bar{X}\beta, d=0), \quad (2)$$

With d as the indicator variable for binary explanatory variables in the model. In the case of continuous independent variables, it can be derived as:

$$\frac{\partial p_i}{\partial x_{ik}} = \Phi(X_i'\beta)\beta_k. \quad (3)$$

For the intensity of adoption (i.e. the number of good practices that traders are using), we estimate count models to capture the count nature of our outcome variable, which ranges between 0 and 5. The Poisson model is our preferred specification here because we have only about 15% of the sample that did not adopt any of the practices. However, we estimate both the zero-inflated Poisson and the regular Poisson models. As in the probit estimations, we calculate the marginal effects (for ease of presentation) for each trader or market characteristic and report the average marginal effect.¹

3. Results

3.1. Descriptive statistics of the tomato traders

Table 1 presents the descriptive statistics of tomato traders in Kaduna and Oyo States. Overall, the majority of traders were male (71%), with a higher proportion in Kaduna (83%) compared to Oyo (31%). The average age of traders was 39 years, with over 14 years of trading experience. Educational attainment varied across states with a surprisingly higher share of traders having at least a secondary education (~66% in Kaduna) compared to about 39% in Oyo. In addition, Kaduna traders were more likely to employ staff (0.47) compared to their Oyo counterparts (0.06). However, Oyo traders had longer membership in product associations (7.5 years) compared to Kaduna traders (3.8 years)². Enclosed stalls were relatively uncommon, though slightly more prevalent in Oyo (19%) than in Kaduna (14%).

Market characteristics also revealed significant differences between the two states. Kaduna traders were more evenly distributed across rural (22%), peri-urban (32%), and urban (46%) markets, while Oyo traders were concentrated in urban markets (77%), with fewer located in peri-urban (11%) and rural (12%) markets. In terms of water access, all Kaduna markets reported some source of water, whereas 5% of Oyo markets indicated no water availability. The main sources of water also differed: Kaduna markets primarily relied on wells (41%) and boreholes (30%), while Oyo markets depended heavily on boreholes (67%). The use of water supplied in jerrycans was reported by 26% of Kaduna traders but was uncommon in Oyo (4%). Pipe-borne water was rare and reported only in Kaduna (4%).

Leadership structures and market size further highlighted contrasts between the states. Oyo markets were more likely to have at least one female in leadership positions (86%) compared to Kaduna (43%). However, selecting leaders by election was more frequently reported in Kaduna (38%) than in Oyo (24%). The number of traders present on a typical market day

¹Given that there could be an association between the decision to adopt the five different recommended practices, we examined the multivariate probit model. We faced convergence challenges that led to the removal of several variables, possibly due (in part) to the low average of 1.7 practices adopted by traders in our sample. Despite these challenges, the signs and statistical significance of the retained variables were consistent between the multivariate probit and individual probit regressions. Therefore, we opted to present the individual probit results for clarity and consistency with the literature. Additionally, we utilized Poisson estimations to analyze factors related to the adoption of multiple practices, which enhances the study.

²For any trader who was not in a product association, the number of years of membership equals zero

Table 1. Descriptive statistics of the tomato trader sample.

	Kaduna	Oyo	Overall
Trader characteristics			
Male (1/0)	0.83 (0.37)	0.31 (0.46)	0.71 (0.46)
Age (in years)	39 (9.95)	43 (13.40)	40 (10.91)
Years of experience trading tomatoes	14 (8.60)	16 (11.04)	15 (9.26)
Trader has at least secondary education (1/0)	0.66 (0.48)	0.39 (0.48)	0.59 (0.49)
Number of hired staff	0.47 (0.97)	0.06 (0.31)	0.37 (0.87)
Years of membership in the product association	3.88 (5.84)	7.55 (8.52)	4.76 (6.76)
The trader has an enclosed market stall (1/0)	0.14 (0.34)	0.19 (0.39)	0.15 (0.36)
Market characteristics			
Located in a rural market (1/0)	0.22 (0.41)	0.12 (0.33)	0.19 (0.39)
Located in a peri-urban market (1/0)	0.32 (0.47)	0.11 (0.31)	0.27 (0.45)
Located in an urban market (1/0)	0.46 (0.49)	0.77 (0.42)	0.53 (0.50)
Market has no water	0.00 (0.00)	0.05 (0.22)	0.01 (0.11)
Market main source is pipe-borne water (1/0)	0.04 (0.19)	0.00 (0.00)	0.03 (0.17)
Market main source is a well (1/0)	0.41 (0.49)	0.24 (0.43)	0.37 (0.48)
Market main source is a borehole (1/0)	0.30 (0.46)	0.67 (0.47)	0.39 (0.49)
Market main source is water in jerrycans (1/0)	0.26 (0.44)	0.04 (0.19)	0.20 (0.40)
Market has at least one female in market leadership	0.43 (0.50)	0.86 (0.35)	0.53 (0.49)
Market leaders are selected by election (1/0)	0.38 (0.49)	0.24 (0.43)	0.34 (0.47)
Number of traders present in the market on typical day	2,760 (3,193)	4,142 (4,224)	3,096 (3,517)
Average distance to town of 50k (km)	4.17 (10.61)	1.7 (5.53)	3.6 (9.69)
Number of observations	370	130	500

Source: Authors calculations.

Table 2. Adoption of good hygiene and handling practices among tomato retailers.

	Kaduna	Oyo	Overall
Trader washes their tomatoes	0.51 (0.50)	0.32 (0.47)	0.46 (0.50)
Trader changes water properly (unconditional)	0.26 (0.44)	0.10 (0.30)	0.22 (0.42)
Trader changes water properly (conditional)	0.46 (0.5)	0.31(0.31)	0.44 (0.49)
The trader washed hands	0.24 (0.43)	0.31 (0.46)	0.26 (0.44)
The trader sorted their tomatoes prior to sale	0.64 (0.48)	0.86 (0.35)	0.70 (0.46)
Tomatoes are sold on a raised platform/table	0.25 (0.43)	0.46 (0.50)	0.30 (0.46)
Number of recommended practices done by trader	1.64 (1.03)	1.95 (1.14)	1.71 (1.06)
Number of observations	370	130	500

Source: Authors calculations.

was larger in Oyo, with an average of 4,142 traders, compared to 2,760 in Kaduna. Kaduna markets were also located further away from towns of 50k (4.17 km) relative to Oyo (1.7 km).

3.2 Adoption rates of good hygiene and handling practices among tomato traders

Table 2 summarizes the adoption of recommended hygiene and handling practices among tomato traders in Kaduna and Oyo States. Overall, adoption rates were relatively low, with traders reporting an average of 1.7 recommended practices. About half of the traders (46%) reported washing their tomatoes before sale, with this practice more common in Kaduna

(51%) than in Oyo (32%). Similarly, among those who washed their tomatoes, only 44% of them reported changing wash water appropriately, with adoption again higher in Kaduna (46%) compared to Oyo (31%). While overall, 22% of traders did not wash their tomatoes, comprising 26% of traders in Kaduna and 10% in Oyo. In contrast, traders in Oyo more frequently reported washing their hands after using the toilet (31%) compared to their counterparts in Kaduna (24%). Sorting tomatoes after purchase was the most adopted practice by about 70% of the overall sample. However, we see some variation across the two states, with 86% of traders in Oyo reporting that they sorted compared to about 64% in Kaduna. The practice of selling tomatoes on raised platforms or tables was reported by 30% of traders overall, but this proportion was significantly higher in Oyo (46%) relative to Kaduna (25%).

3.3 Factors associated with the adoption of recommended practices among traders

Table 3 presents the regression results examining the factors associated with the adoption of recommended practices among traders across both states. Seven key points emerge. First, we find that age and experience matter. Older traders were more likely to change their wash water properly, all else equal. While traders with more years of experience were less likely to change their wash water appropriately, they are more likely to wash their hands. Second, educational attainment plays an important role for some practices. More specifically, traders with at least a secondary education were significantly more likely to wash their tomatoes. These effects large in magnitude with a 14 percentage points higher probability.

Table 3. Factors associated with the adoption of recommended practices among traders.

Variables	(1) Washing	(2) Change water properly	(3) Hand washing	(4) Sorting	(5) Sell on a raised platform/table
Male trader (1/0)	-0.025 (0.056)	0.073 (0.079)	0.060 (0.053)	-0.074 (0.054)	-0.039 (0.050)
Age in years	-0.001 (0.003)	0.012*** (0.004)	-0.003 (0.003)	-0.004 (0.003)	-0.004 (0.003)
Years of experience trading tomatoes	-0.002 (0.003)	-0.019*** (0.005)	0.006* (0.003)	-0.004 (0.003)	0.001 (0.003)
Trader has at least secondary education (1/0)	0.140*** (0.047)	0.024 (0.073)	0.026 (0.044)	0.025 (0.047)	0.021 (0.045)
Number of hired staff	-0.072*** (0.028)	0.076 (0.061)	0.072*** (0.025)	0.040 (0.030)	0.020 (0.028)
Years of membership in the product association	-0.004 (0.004)	0.020*** (0.006)	-0.001 (0.003)	0.007* (0.004)	-0.001 (0.004)
The trader has an enclosed market stall	0.050 (0.067)	0.121 (0.092)	0.057 (0.061)	-0.121** (0.059)	0.157*** (0.058)
Trader is in Oyo State	-0.125** (0.063)	-0.195* (0.107)	0.151*** (0.054)	0.202*** (0.067)	0.154*** (0.056)
Located in a peri-urban market (1/0)	0.163** (0.070)	0.053 (0.096)	-0.019 (0.066)	0.123** (0.062)	0.047 (0.069)
Located in a rural market (1/0)	-0.082 (0.074)	-0.166* (0.101)	-0.120* (0.062)	0.030 (0.070)	-0.022 (0.068)
Market main source is pipe- borne water (1/0)	1.267*** (0.153)	0.133 (0.243)	1.160*** (0.193)	-0.226 (0.242)	0.071 (0.250)

Table 3. *Continued*

Variables	(1) Washing	(2) Change water properly	(3) Hand washing	(4) Sorting	(5) Sell on a raised platform/table
Market main water source is well (1/0)	1.668*** (0.091)	0.104 (0.112)	1.320*** (0.107)	-0.022 (0.212)	0.266 (0.199)
Market main source is a borehole (1/0)	1.587*** (0.091)	-0.142 (0.116)	1.354*** (0.102)	0.020 (0.210)	0.318 (0.195)
Market main source is Jerrycan (1/0)	1.552*** (0.117)		1.219*** (0.135)	-0.067 (0.222)	0.158 (0.213)
Market has at least one female in market leadership	0.092* (0.054)	-0.234*** (0.072)	-0.071 (0.052)	0.085* (0.051)	0.092* (0.050)
Market leaders are selected by election (1/0)	0.143** (0.063)	0.057 (0.097)	0.124** (0.057)	0.072 (0.063)	0.084 (0.060)
Number of traders present in the market on typical day	-0.010 (0.007)	-0.005 (0.011)	-0.011 (0.007)	0.002 (0.007)	-0.023*** (0.007)
Average distance to town of 50k (km)	0.002 (0.003)	-0.006* (0.004)	-0.001 (0.003)	-0.002 (0.002)	-0.006** (0.003)
Toilet to trader ratio			-0.871 (1.121)		
Number of observations	494	233	494	494	494

Standard errors in parentheses.

***p < 0.01,

**p < 0.05,

*p < 0.1. Six (6) observations were missing, which led to a reduction to 494. The regressions for routine water change are only estimated on the sample of those who wash their tomatoes.

Third, the scale of the enterprise (proxied by the number of hired staff) influenced adoption differently across practices. Surprisingly, retailers with more hired staff were less likely to wash tomatoes but more likely to wash their hands. Fourth, we find that traders with longer years of membership in the product association were reported to be more likely to sort their tomatoes. Fifth, we find consistent evidence of State-level differences. Holding other factors constant, traders in Oyo State were less likely than their Kaduna counterparts to wash tomatoes and change water properly, but were more likely to wash their hands, sort tomatoes and sell on raised platforms. Sixth, we find that market location and infrastructure were key factors in explaining adoption. Compared to retailers in urban markets, retailers being in a peri-urban markets was associated with a 16 and 12 percentage point higher probability of them washing and sorting tomatoes, all else equal. Similarly, trading in a rural market is associated with a 17 and 12-percentage-point lower probability of changing wash water appropriately or washing of hands compared to those in urban markets, all else equal. Market water sources were strongly associated with the adoption of recommended practices. Compared to having no water or water from a stream, traders in markets with water supplies from pipes, wells, boreholes and jerrycans were more likely to wash their tomatoes, change water properly and wash their hands. By contrast (and not surprisingly), water sources showed no significant influence on sorting or selling on raised platforms.

Seven, we find that market governance was associated with trader adoption of recommended practices. More specifically, retailers in markets with at least one woman in the market leadership (i.e. as the market leader or member of the executive committee responsible for the day to day running of the market) were more likely to wash their tomatoes (9-percentage point higher probability), sort (8.5-percentage points higher probability) and sell on raised platforms (9-percentage point higher probability). Interestingly, we find that conditional on washing, traders in markets with at least one woman in the

market leadership were less likely to change water routinely. We also find that traders in markets with election-based leadership were more likely to wash tomatoes and wash their hands. These effects are also significant in magnitude with a 14 and 12 percentage point higher probability of adoption respectively, all else equal.

Eight, we find evidence that other market characteristics related to infrastructure and capacity matter. Retailers in larger markets (higher number of traders present on a typical day), and more remote markets (whose average distance to the town was 50,000 km was higher) were less likely sell on a raised platform and traders operating out of an enclosed stall (vs. an open space) were less likely to sort their tomatoes but more likely to sell their tomatoes on raised platforms.

3.4 Factors associated with the number of recommended practices adopted by traders

Next, we explore the factors influencing the number of recommended practices adopted by traders overall, and by state as shown in Table 4. Four key points stand out. First, we confirm regional differences between Kaduna and Oyo. Tomato retailers in Oyo State are more likely to adopt more of the recommended practices compared to their counterparts in Kaduna, all else equal. Second, we find that on average, retailers with at least a secondary education and those in peri-urban areas tend to adopt more of the recommended practices compared to those with less education and in urban or rural areas. Third, we find that water access is positively associated with the adoption of more of the good practices, particularly access to water via a well and boreholes. Fourth, we confirm again that market governance matters. Retailers in markets whose leaders are selected via regularly held elections (vs. appointment or volunteering) tend to have traders adopting a higher number of practices.

Table 4. Factors associated with the number of recommended practices adopted by traders.

Variables	Poisson	Zero-inflated Poisson
Male trader (1/0)	-0.040 (0.143)	-0.100 (0.112)
Age in years	-0.005 (0.008)	-0.002 (0.007)
Years of experience trading tomatoes	-0.007 (0.009)	-0.010 (0.007)
Trader has at least a secondary education (1/0)	0.303** (0.130)	0.243** (0.106)
Number of hired staff	0.036 (0.083)	0.033 (0.065)
Years of membership in the product association	0.003 (0.010)	0.002 (0.009)
The trader has an enclosed market stall	0.231 (0.157)	0.160 (0.141)
Trader is in Oyo State	0.280* (0.154)	0.175 (0.128)
Located in a peri-urban market (1/0)	0.395** (0.191)	0.208 (0.149)
Located in a rural market (1/0)	-0.285 (0.210)	-0.292* (0.174)
Market main source is pipe-borne water (1/0)	-0.205 (0.829)	0.326 (0.486)
Market main source is well (1/0)	1.392*** (0.521)	1.134*** (0.279)
Market main source is a borehole (1/0)	1.307** (0.521)	0.927*** (0.277)

Table 4. *Continued*

Variables	Poisson	Zero-inflated Poisson
Market main source is Jerrycan (1/0)	0.863 (0.577)	0.723** (0.336)
Market has at least one female in market leadership	0.113 (0.160)	-0.050 (0.123)
Market leaders are selected by election (1/0)	0.483*** (0.151)	0.450*** (0.121)
Number of traders present in the market on typical day	-0.041* (0.021)	-0.020 (0.017)
Average distance to town of 50k (km)	-0.007 (0.008)	-0.003 (0.006)
Toilet to trader ratio in the market	2.015 (3.767)	4.378* (2.305)
Observations	494	494

Standard errors in parentheses.

*** $p < 0.01$,

** $p < 0.05$,

* $p < 0.1$. Six (6) observations were missing, which led to a reduction to 494.

4. Discussion

Our empirical analysis reveals variation in the adoption of recommended practices among tomato retailers in Nigeria, reflecting both regional and market-level differences. Adoption rates were generally low. Apart from product sorting (adopted by 70% of respondents), most practices were followed by only 20–50% of traders, with an average trader implementing about 1.9 of the five studied practices. These results underscore persistent public health risks associated with food handling in traditional African markets, consistent with previous research (Boakye et al., 2023; Erinle & Ajayi, 2022; Gemedo et al., 2023; Imafidor et al., 2018).

Contrary to our expectations given national statistics of lower education and higher poverty rates in the north (CableIndex, 2025; Otekunrin et al., 2019), our sample of traders in Kaduna were slightly better educated and more likely to hire staff than their counterparts in Oyo. Kaduna retailers were also more evenly distributed across rural, peri-urban, and urban markets, whereas Oyo traders were concentrated in urban areas and had longer membership in trader associations. These patterns suggest structural variations in market organization and trader profiles between the two states. Contextual infrastructure also varied: boreholes were the main water source in Oyo, while wells predominated in Kaduna, potentially influencing water quality and availability. Gender dynamics also differed. Oyo markets had a higher likelihood of having female leaders, who have been shown to influence hygiene compliance (Hirai et al., 2016), whereas female leadership in northern markets remains limited, consistent with broader trends in Nigeria (Kucici & Buratai, 2025; Osuntade et al., 2025).

Overall, adoption of recommended hygiene and handling practices was low in both study states, constrained by limited knowledge, poor market infrastructure and heterogeneous governance systems. Traders often operate under economic and environmental pressures that make consistent hygiene difficult. Practices requiring water, such as produce washing and water changing were more common among Kaduna retailers, while Oyo retailers were more likely to employ structural hygiene measures, such as sorting and displaying tomatoes on raised platforms.

Regression analysis further highlighted the importance of individual and market factors. Older traders were more likely to change wash water properly, consistent with Abatan et al. (2025). Formal education strengthened food safety knowledge, aligning with findings both within and outside Nigeria (Adebayo & Oyetola, 2021; Hamed & Mohammed, 2020). We find that trading experience had mixed effects. It positively influenced general hygiene but negatively affected water-changing, suggesting entrenched habits that are resistant to change and emphasizing the need for retraining. Traders with more hired staff were less likely to wash tomatoes but were reported to wash their hands, likely reflecting a delegation paradox where assistants handle tasks without adequate training or motivation, a phenomenon also documented in Asia (Kariuki et al., 2017). Membership in trader associations positively influenced practices such as sorting, reflecting the role of accumulated experience, exposure to norms, and access to information.

A key finding of this study is that market characteristics, particularly market governance matters. Access to improved water sources such as wells, boreholes and in some cases jerrycans consistently predicted washing, water changing and hand washing. This reinforces the centrality of water infrastructure in reducing microbial and other contamination risks along vegetable value chains. Location also mattered: peri-urban traders were more likely to adopt washing and sorting, while rural traders were less likely to change water or wash their hands. This may be because of a larger space available in the peri-urban markets, which allowed them to wash and sort their tomatoes compare to markets in the urban areas which are largely populated and crowded and possibly have less spaces available to each trader. These findings likely reflect both consumer demand pressures and infrastructural limitations (Aluh & Aluh, 2017; Petrikova et al., 2024; Shahnum & Shah, 2024).

Market governance structures also influenced study outcomes. Markets with elected leadership had higher adoption rates of the recommended practices, possibly due to stronger accountability structures and enforcement mechanisms. Women's engagement in market leadership was mixed. It was positively associated with washing, sorting and sales on raised platforms, all else equal. However, it was negatively associated with changing water routinely, conditional on washing the tomatoes. This might reflect limited knowledge about the importance of not just washing but changing the water used for washing regularly. Together, these results on market governance highlight some of the values of inclusive governance systems beyond ensuring that leadership structures reflect their followers in terms of demographic composition. More inclusive systems can support and reinforce good hygiene and handling practices but additional work is needed to understand the mechanisms through which these governance structures and inclusive leadership affect the design and enforcement of rules associated with food safety. Larger markets, with more traders, were associated with lower adoption, possibly due to reduced oversight and congestion.

In summary, our findings indicate that both individual trader characteristics and market-level structures—particularly infrastructure, governance, and location—significantly shape the adoption of hygiene and handling practices and thus need to be considered alongside differences in culture and education.

5. Conclusions and policy implications

This study revealed both similarities and key differences between tomato retailers in northern vs. southern Nigeria, underscoring the complex interplay between sociodemographic characteristics, market infrastructure, and governance in shaping food safety practices along the tomato value chain in Nigeria. Overall, the adoption of recommended hygiene and handling practices was low, with tomato retailers reporting fewer than two practices on average. Washing tomatoes and changing wash water appropriately were more common in Kaduna, while sorting and selling on raised platforms were more prevalent in Oyo, reflecting context-specific patterns of behavior.

The results demonstrate that education, experience, access to clean water, and market governance are critical determinants of hygiene adoption. Traders with higher education and those in markets with improved water sources were consistently more likely to implement recommended practices. In contrast, older and more experienced traders were sometimes less inclined to change established habits, and larger, more congested markets tended to show weaker compliance. Markets with elected leadership were more proactive in promoting hygiene and proper vegetable washing practices, while the influence of women in leadership was positively associated with washing, sorting and sales on raised platforms but negatively associated with changing the water used for washing routinely.

Improving food safety in Nigeria's tomato markets requires multi-level and context-sensitive interventions. Education and behavior change campaigns should target traders with limited literacy or entrenched routines, while infrastructural investments are essential to expand access to reliable water supplies and sanitation facilities. Strengthening market governance through transparent, election-based leadership and active trader associations can further enhance accountability and compliance with hygiene standards.

Overall, the findings highlight the need for integrated food safety governance that links infrastructural investment, institutional support, and behavioral change at the market level. Tailoring interventions to local demographic and governance contexts will be vital for improving hygiene compliance, reducing foodborne disease risks, and safeguarding public health in Nigeria's informal food systems.

Ethical approval and consent statement

All studies in this project involving humans were approved by Michigan State University Institutional Review Board and were conducted in accordance with the local legislation and institutional requirements. This project has the Michigan State University IRB Study ID: STUDY00007403 and was determined exempt Category: Exempt 2ii. Informed consent was obtained verbally from all participants after explaining the purpose of the study and prior to survey administration.

Verbal consent was chosen because many traders had limited literacy and time constraints within the market environment, making written consent impractical; however, participation was entirely voluntary. The authors used AI tools (Grammarly and ChatGPT) only for language editing and applied to the authors' original writing.

Data availability Statement

Data will be made available on request.

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